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Effects of competition between short-rotation willow and weeds on performance of different clones and associated weed flora during the first harvest cycle

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ABSTRACT

In order to assess the ability of willow clones to compete with weeds, willow shoot biomass and plant mortality were measured over the first harvest cycle for 10 commercial and two breeding clones at three different sites in southern Sweden. Two levels of weed pressure (weeded and not weeded) were employed and the effects of cutback or not after the first growing season were compared for willow clones under weed pressure. There were significant differences between clones in their ability to compete with weeds, measured as willow shoot growth reduction in plots with weeds, at two of the three sites. However, shoot biomass reduction due to weeds was large in all the clones, with Stina and SW Inger among the least affected. Mean shoot growth reduction after the first harvest cycle for the commercial clones was 68.3%, 91.2% and 94.3% at the three sites and the corresponding plant mortality was 9.8%, 57.3% and 56.2% under weed pressure. Significant clonal differences in yield, under weed-free conditions, were found at all three sites. Significant clone-site interactions were found for both growth reduction and biomass production. Cutting back shoots after the establishment season, under weed pressure, resulted in higher mean plant mortality and lower mean willow shoot biomass after one harvest cycle at two of the three sites. The weed flora was initially dominated by annuals, but became dominated by perennial weeds during the first harvest cycle.

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1. Introduction

Plantations of willow shrubs (*Salix* spp.) managed as short-rotation coppice (SRC) have provided biomass for energy purposes for more than two decades in Sweden. The high energy ratio, i.e. energy generated divided by energy input [1,2], and the high yield potential compared with other energy crops [3] make willow a viable alternative for generation of bioenergy from agricultural land. However, cultivation of biomass willow has not met the expectations that farming organisations, government agencies and scientists once had when this crop was commercialised in the late 1980s, in terms of number of hectares grown, biomass yield and economic return [4,5]. Several reasons for this have been suggested with reduced growth due to weed problems being one important agronomic factor [4]. Willow SRC is severely hampered by weeds during the establishment year both in terms of growth [6–8] and plant survival [8]. If weeds are not controlled during the establishment year, this has a negative effect on yields in subsequent seasons [9].

The estimated mean annual yields of well managed Swedish plantations range from 4.0 to 6.3 t ha^{-1} dry matter during the first harvest cycle. However, the yield can be much lower if crop management is neglected [5]. New cultivars are continually being released from breeding programmes and some of these can yield 60% more than the cultivars used when willow SRC was first introduced as a bioenergy crop [10]. Therefore, there is potential to increase the yield in commercial plantations by choosing the best clones. However, yield data for the most recently released clones in Sweden are limited, making cultivar choices uncertain, especially in relation to local adaptation.

Commercial breeding of biomass willow was initiated in Sweden in 1987 by Svalöf AB. Since the start of the breeding programme, resistance to certain pests and diseases has been one of the main breeding goals, while there has been no deliberate selection for competitive ability in relation to weeds [11]. Weed competitiveness can be partitioned into two components, weed suppression ability and weed tolerance. Weed suppression ability is the ability of a crop to reduce weed growth through competition, while weed tolerance is the ability of a crop to achieve high yields despite weed competition [12,13]. If differences exist between willow clones in weed competitive ability it would be possible to select for this trait during breeding. Albertsson et al. [8] found only small differences in weed tolerance between 12 willow biomass clones during the establishment year. In other crops such as wheat [12], soybean [14] and maize [15], there are differences between cultivars in their ability to compete with weeds. However, willow SRC is a perennial crop, commonly planted with less than 13×10^3 of un-rooted cuttings per hectare. This low plant density compared to other agricultural crops is one factor that makes this crop a poor weed competitor during the establishment year. Hence, more long-term studies are needed to determine whether clonal differences in weed competitiveness exist in willow.

Cutting back the first year's shoot growth (cutback) is common practice when establishing a willow plantation [16]. This is mainly done to increase the number of shoots per plant and to facilitate fertilisation and additional weeding during the second growth season [17]. However, this practice has not been shown to increase yield [16,18]. Cutback might also affect the ability of the willow plants to compete with weeds, especially at the beginning of the second growing season, since several weed species and cut willow plants will start to grow from approximately the same height.

The objectives of this study were thus: 1) to evaluate the weed competitive ability of 10 commercial willow clones, and two breeding clones, during the first harvest cycle; 2) to investigate the weed succession of willow plantations during the first harvest cycle 3) to estimate the shoot biomass yield of 10 commercial clones during the first harvest cycle with thorough weeding; and 4) to evaluate whether cutting back the first year's shoot growth affected the growth of willow clones during the first harvest cycle when grown under severe weed pressure. In order to cover various edaphic conditions and differences in weed flora, the study was conducted at three sites in southern Sweden.

2. Material and methods

2.1. Management and experimental design

The preparation, planting, management and local conditions of the three trial sites (J, P and S) and the pedigree of the clones are described in detail in a previous paper [8]. That paper focuses on the establishment year whereas this paper mainly focuses on the two subsequent growing seasons. The trials were laid out in strip-plot design with three treatments ('Weeded', 'Unweeded' and 'Unweeded-no cutback') and 10 commercial clones (Gudrun, Karin, Klara, Linnea, Lisa, Stina, Sven, SW Inger, Tora, Tordis), in four blocks at each site. At site S two breeding clones were added. Cuttings were planted in double rows (1.5 m and 0.75 m spacing between and within double rows, respectively and 0.7 m between cuttings) in April 2010. Total number of plots, each containing 80 cuttings in four double rows [8], was 120 at sites J and P and 144 at site S. Within each block, clones and treatments were randomised to rows and columns, respectively. Weeds were removed mechanically and by hand-hoeing before they began to compete with the willow plants during all three years in the 'Weeded' treatment. The number of weeding occasions differed between the sites due to differences in weed pressure. No weeding was performed in the other treatments. All shoots in the 'Weeded' and 'Unweeded' treatments were cut back to approx. 5 cm above the ground during January–February 2011 (after one growth season), when plants were in a dormant state. No cutback was performed in the 'Unweeded-no cutback' treatment. All treatments were fertilised on 4 May 2011 with 100 kg ha^{-1} of nitrogen (Axan, Yara) applied using a boom spreader. The weather conditions at the three sites were similar since they were less than 1.5 km apart. Annual precipitation was approx. 730 mm, 740 mm and 565 mm in 2010, 2011 and 2012, respectively. The average annual precipitation during the period 1961 to 1990 in this area was approx. 600 mm [19].